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PROGRESS REPORT
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FOR
SKYLAB STUDY OF WATER QUALITY
NASA CONTRACT NAS 9-13271

EREP PROPOSAL NO. 540-G1
TASK-347
SITES-416 + 423
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SUMMARY OF RESEARCH OBJECTIVES

Two Kansas reservoirs will be studied using Skylab data in conjunction with simultaneous ground truth information in an attempt to detect and monitor various parameters of water quality. Water samples will be collected from the reservoir or reservoirs under investigation and low-level aircraft support missions will be flown to acquire photographs which will approximate the spectral coverage of forthcoming Skylab photographs. Image analysis and data processing techniques will be developed to aid in the correlation of Skylab data with ground truth data and supporting aerial photography.

A. OVERALL STATUS

EREP data products thus far received for the Sept. 18, 1973 SL3 pass over southeast Kansas include S-190A positive transparencies. These photos cover three lakes, Toronto, Fall River, and Elk City reservoirs. Concurrent with satellite overflight, field crews were on all three lakes collecting water samples. These samples were analyzed for concentrations of bicarbonate, carbonate, calcium, magnesium, potassium, sodium, sulfate and chloride. In addition, total solids, total heat-stable solids, suspended solids, heat-stable suspended solids, and pH were determined.

The four black and white S-190A products were analyzed quantitatively with a Macbeth EP-1000 macrodensitometer. The bands analyzed were 0.5-0.6 μ green (roll 48), 0.6-0.7 μ -red (roll 47), 0.7-0.8 μ -first infrared (roll 43), and 0.9-1.0 μ -second infrared (roll 44). Measurements were made on 4 X enlarged transparencies since the lakes appeared too small on the 70 mm format for accurate measurements. The aperture size used was 1 mm.

Five locations were selected on Fall River and Toronto Reservoirs, and four from Elk City. Each density measurement was centered as nearly as possible over one or more ground truth sampling station. Attempts were then made to relate film density to corresponding water quality parameters. Previous experience in working with ERTS imagery has shown that suspended solids dominate the appearance of Kansas reservoirs in satellite imagery in the visible and near-infrared region.

In Figure 1 density is plotted against suspended solids for all three lakes and for all four bands of black and white photography. The sample stations show a range in suspended solids from about 25 ppm to nearly 90 ppm. Based on extensive sampling of Kansas Reservoirs the last 2 years, these figures represent relatively clear water. In general these lakes are well mixed, in that the suspended solids measurements of each lake fall within a small range of values. These measurements substantiate the visual and IDECS analyses of the photos which failed to detect major tonal variations within any of the lakes. Some variation in tone does exist however, and this is especially evident in the red and green bands. In general both bands show a correlation with suspended solids that decreases with increasing concentrations. The red band to some extent and particularly the green band density levels for Elk City Reservoir are unexpectedly low. Atmospheric factors may be responsible for the lighter tones of Elk City since green light is more susceptible to scattering by atmospheric particulates. A weather front in the vicinity and pollutants from nearby oil refineries are possible causes of variation in atmospheric turbidity in this area.

The infrared film densities decrease slightly with higher amounts of suspended solids. This smaller degree of sensitivity to concentrations of suspended material would be anticipated due to the greater amount of absorption of infrared energy by water.

Vincent (1972) has suggested band ratios as a means of suppressing sun-angle dependence and atmospheric effects. Such band ratios were used in a recently completed ERTS-1 study of water quality (Yarger and McCauley, 1974) and were quite useful in correlating data collected at different sun angles and atmospheric conditions. In an attempt to improve correlation between Skylab data and ground truth, red/green band ratios were computed and plotted against suspended solids.

Before ratioing, density measurements were converted to values proportional to radiance detected by the S-190A sensor. If the reservoir densities are in the linear region of the density vs. log (exposure) curve for the film, then the ratio can be written as

$$\frac{E_i}{E_j} = k \frac{10^{-D_i}}{10^{-D_j}}$$

where E_i and E_j are band i and j radiances from the target and D_i and D_j are corresponding film densities.

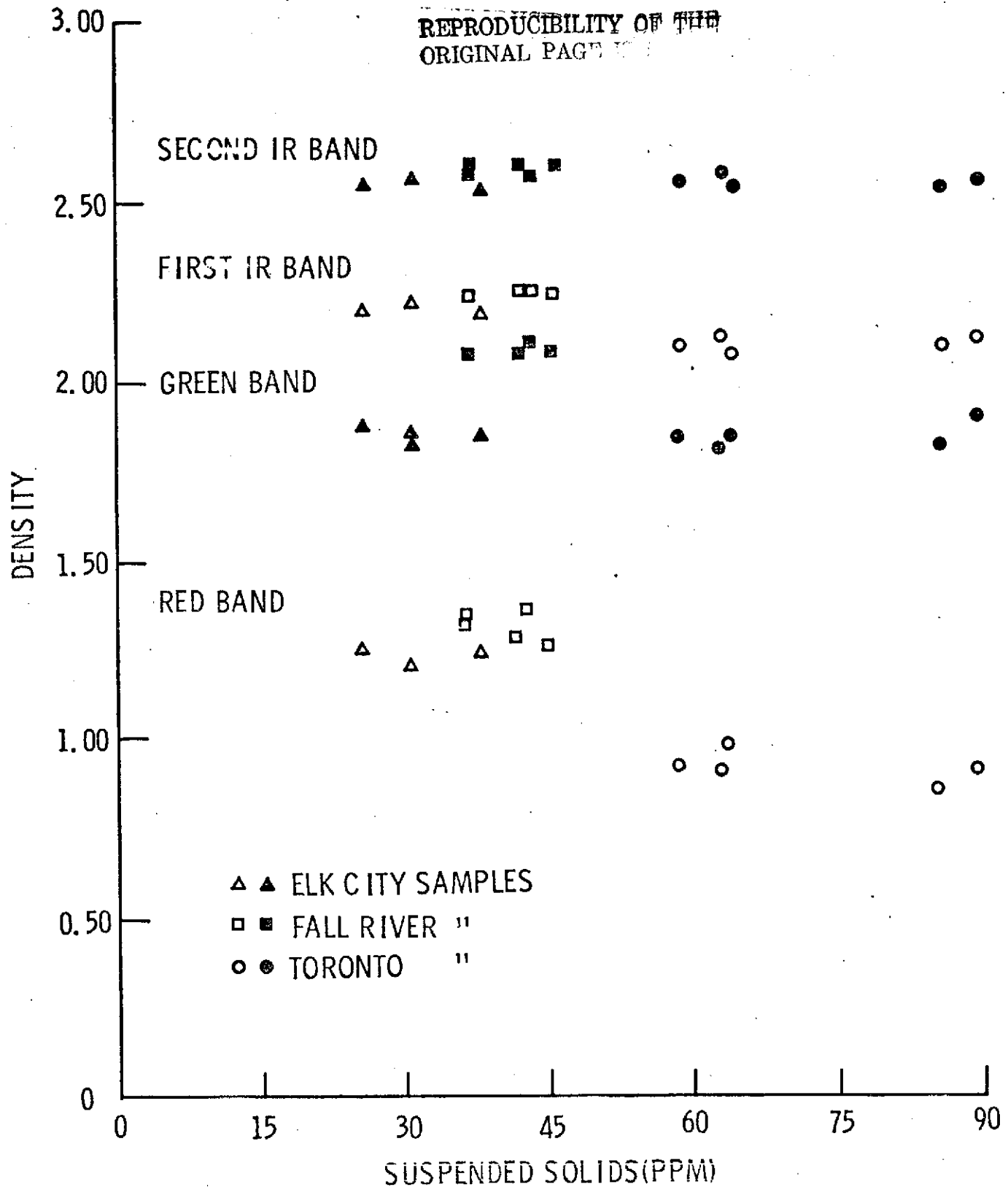


FIGURE 1. S-190A IMAGE DENSITY VS. SUSPENDED SOLIDS FOR
WATER SAMPLES TAKEN FROM 3 SOUTHEAST KANSAS
RESERVOIRS , SEPT. 18 1973.

K is a constant determined by the slope of the D vs. log E curve which relates the density of our film copy to the original exposure on Skylab. K also depends on filter and camera face attenuation coefficients. This constant has not yet been determined but is immaterial in establishing correlation between imagery and sample analysis. The red to green band ratio is shown in Figure 2 and exhibits a good linear dependence on suspended solids with RMS residual of 6 ppm. A similar plot is shown in Figure 3 in which comparable ERTS-1 data is plotted. MSS 5(Red) over MSS 4 (Green) is equivalent to the red to green S-190A ratios. Figure 3 represents substantially more data collected during a year of ERTS imaging under varying conditions of illumination and sky conditions and over a wide range of suspended solids concentration. The Skylab data (Figure 2) compares favorably to the ERTS data (Figure 3) in the region 0-80 ppm. Beyond 80 ppm the ERTS MSS red/green ratio flatten out. We would expect the Skylab S-190A red/green ratio to also flatten out, but the relatively clear water sampled does not permit confirmation of this. The highest two points in Figure 2 do, perhaps, indicate a similar flattening.

B. RECOMMENDATIONS CONCERNING DECISIONS AND/OR ACTIONS
REQUIRED TO ENSURE ATTAINMENT OF THE EXPERIMENTS SCIENTIFIC
OBJECTIVES

NONE.

C. EXPECTED ACCOMPLISHMENTS DURING THE NEXT REPORTING PERIOD.

During the next period, attempts will be made to cross-calibrate our densitometer to the one at the Photographic Technology Division of Johnson Space Center in an effort to drive radiometric data from our copies of S-190A photography. This data will then be compared with our ground truth measurements of water quality in a manner similar to that outlined in this report except that actual radiance values will be used instead of values proportional to radiance. Analysis of S-192 data will begin during the next period when such data becomes available.

D. SIGNIFICANT RESULTS AND THEIR RELATIONSHIP TO PRACTICAL APPLICATIONS OR OPERATIONAL PROBLEMS.

Analysis of S-190A imagery from 1 EREP pass over 3 reservoirs in Kansas establishes a strong linear correlation between the red/green radiance ratio and suspended solids. This result compares quite favorably to ERTS MSS CCT results. The linear fit RMS for Skylab is 6 ppm as compared to 12 ppm for ERTS. All of the ERTS satellite passes yielded fairly linear results with typical RMS values of 12 ppm. However, a few of the individual passes did yield RMS values of 5 or 6 ppm which is comparable to the one Skylab pass we were able to analyze. In view of the cloudy conditions in the Skylab photo, yet good results, the indications are that S-190A may do somewhat better than the ERTS MSS in determining suspended load. More S-190A data is needed to confirm this. As was the case with the ERTS MSS, the Skylab S-190A showed no strong correlation with other water quality parameters.

S-190B photos because of their high resolution can provide much first look information regarding relative degrees of turbidity within various parts of large lakes and among much smaller bodies of water.

E. SUMMARY OUTLOOK FOR THE REMAINING EFFORT TO BE PERFORMED

Because of the delay in the delivery of the S-192 computer compatible tapes a time and cost extension of 5 months has been requested for this contract. Based on our analysis of S-190A and B photography we expect S-192 data to exhibit excellent quantitative correlation with suspended load in Kansas reservoirs. The five-month extension if granted would allow the complete analysis of the forthcoming S-192 CCT's and would establish May 30, 1975 as the new completion date for this project.

F. TRAVEL SUMMARY AND PLANS

NONE.

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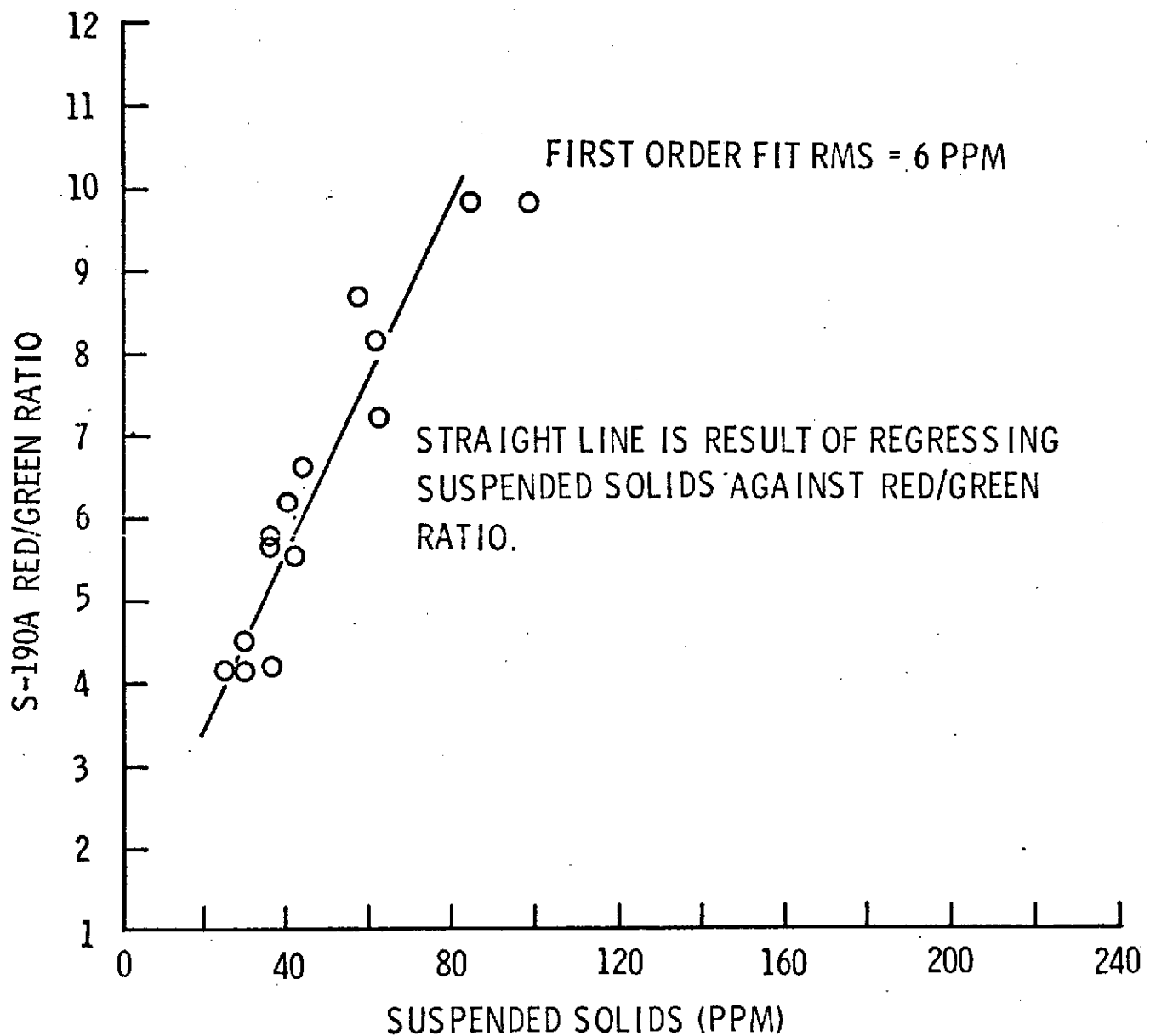


FIGURE 2. RED/GREEN RADIANCE RATIOS VS. SUSPENDED SOLIDS FOR WATER SAMPLES TAKEN FROM 3 SOUTHEAST KANSAS RESERVOIRS , SEPT. 18 1973 (RED/GREEN RATIO IS DEFINED IN TEXT).

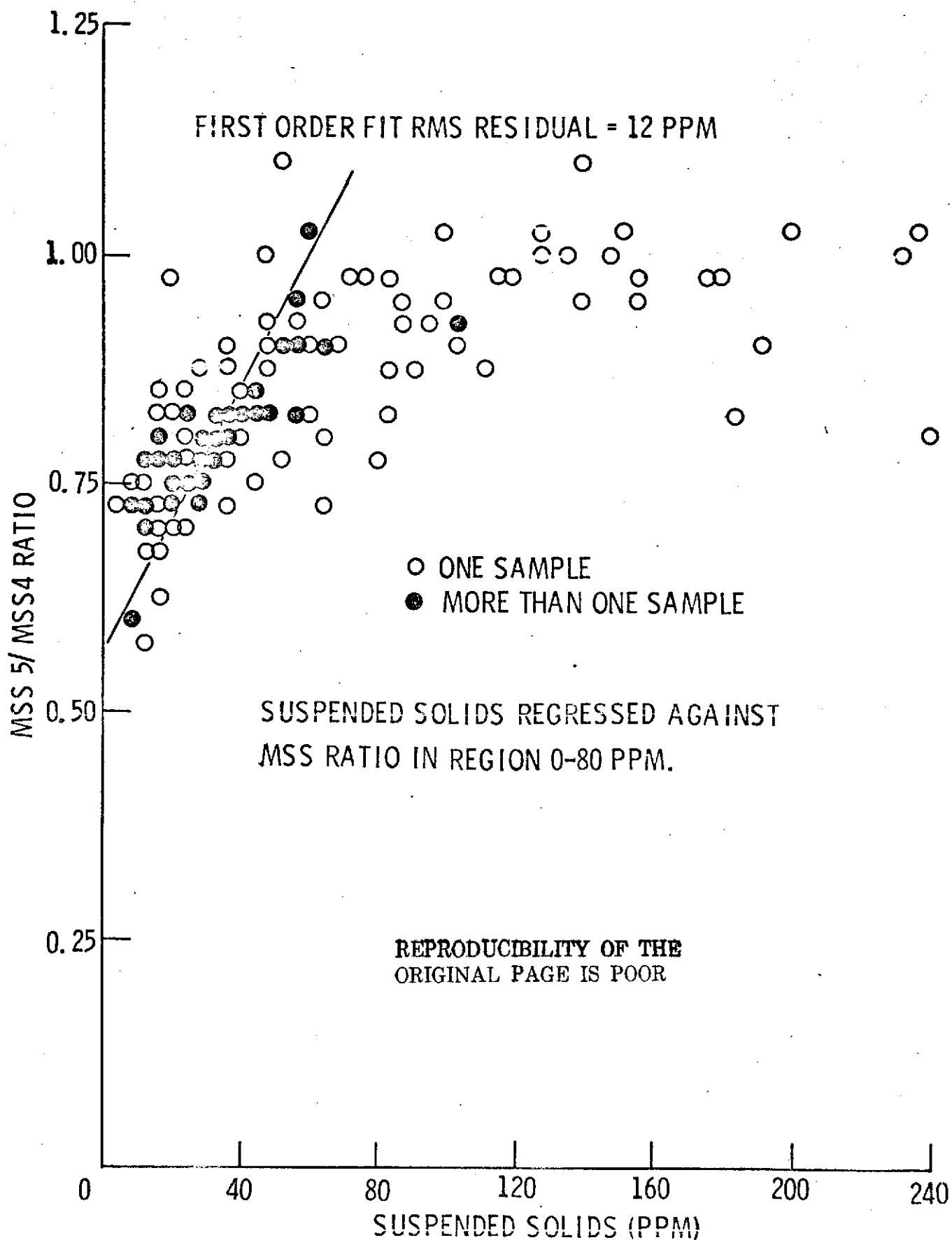


FIGURE 3. MSS 5/MSS 4 CCT RATIO VS. SUSPENDED SOLIDS FOR 167 WATER SAMPLES TAKEN FROM 3 KANSAS RESERVOIRS DURING 13 DIFFERENT ERTS-1 CYCLES.

FINANCIAL REPORT

A statement of financial status for this project will be sent under separate cover by the CRINC accounting office.

REFERENCES

- Vincent, Robert K., (1972), "An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds": Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, Oct. 2-6, pp. 1239-1243.
- Yarger, H. L., J. R. McCauley, (1974), Kansas Environmental and Resource Study: A Great Plains Model; Monitoring Fresh Water Resources, Final Report. NASA Contract No. NAS 5-21822 Task 5.